large distances while the bomber is flying to the Soviet Union, however, the bomber might need to receive this estimate when close to the Soviet Union to keep the potential search area to a manageable size.

- **Target Recognition.** Because a bomber's sensors would provide voluminous data while a target search is under way, some form of computerized target recognition system is probably required to sort the data and alert a bomber crew to a potential target.

- **Ability to Distinguish Targets from Decoys.** The target recognition software and the crew must be able to distinguish actual missiles from decoys; also, they must not be deceived by simple countermeasures that change the radar and infrared properties of a mobile target.

- **Minimal Vulnerability to Air Defenses.** The altitude, speed, and radar emissions of the bomber during a search must not make it unduly vulnerable to air defenses, including anti-aircraft guns and tactical surface-to-air missiles.

The United States is a long way from being able to meet these basic requirements. Neither radar nor infrared sensors provide the required resolution; the needed target recognition software has not been developed; and current search systems would be vulnerable to decoys and simple countermeasures.

In addition, there are inherent challenges in using a bomber such as a B-1B as the sensor platform. If the bomber flies close to the ground at 200 to 400 feet to hide from enemy air defenses, the swath covered by its sensors is limited, increasing the distance the bomber must travel to search a given area. The demand for extended range is severe even when the search area is relatively small. For example, if the area being searched is the territory within 20 miles of where the mobile target was last detected and the sensors on the bomber have a clear view of the land 2,000 feet to either side of the bomber, then the bomber would have to fly about 1,700 miles to cover the search area.

On the other hand, if a bomber flies higher--say, at 1,000 feet--the sensors can cover a wider swath but the bomber is much more exposed to detection by ground-based radars and vulnerable to anti-aircraft fire and surface-to-air missiles. In addition, if the bomber employs active sensors like radar, those sensors might alert the air defense forces to the bomber's presence.

Finally, the United States does not currently have a system of cueing--instructing a bomber where to search for a particular mobile target--that could decrease the size of the area the bomber must search. To establish such a system, the United States needs space-based sensors or other technical means for locating the mobile targets when they are deployed in the field. Once such sensors are developed and deployed, the United States needs a method to process the data and get it to the bomber while en route to the Soviet Union.[6] Thus, the United States is a long way from having the basic elements in place that will make a bomber such as the B-1B an effective weapon against targets such as mobile Soviet missiles.

Moreover, when the most difficult challenge--finding effective sensors--is met, it may become evident that bombers are not the preferred weapon for the task. For example, the sensors might operate best at medium or high altitudes and, if so, it might make more sense to carry them on expendable drones. If relatively precise data on the location of mobile missiles can be obtained from high-altitude reconnaissance aircraft or from satellites, the most reliable and inexpensive system for destroying mobile missiles might involve relaying the location to either ballistic missiles or cruise missiles.

Conventional Missions. Modern anti-aircraft guns and tactical surface-to-air missiles are now possessed by nations in many regions in the world, making it increasingly risky for a bomber to fly over a target and drop bombs.[7]

In conventional warfare, therefore, there is a growing effort to equip bombers to stand off from the target and attack it with pre-

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6. The MILSTAR satellite communication system is a candidate for the data link because the system will employ high frequencies that are relatively immune to disruption by the effects of high-altitude nuclear detonations.

7. Risk in conventional missions is commonly evaluated by a different standard than risk in nuclear missions. For example, 30 percent to 40 percent attrition might be considered a success for a strategic nuclear mission, while 5 percent attrition per sortie might be judged unacceptable for conventional missions.

cision-guided munitions such as glide bombs, short-range air-to-surface missiles, and cruise missiles. Since a standoff strategic bomber would be effective in performing these conventional missions, the demands of conventional warfare do not necessitate maintaining a strategic penetrating bomber.

This study cannot reconcile these many arguments and reach a conclusion about the desirability of penetrating bombers compared with standoff bombers. Indeed, as is the case with so many arguments about national defense, there is no clear answer. Nonetheless, questions about the desirability of retaining the capability to penetrate Soviet air defenses should be kept in mind as the Congress considers enhancements to the B-1B bomber.

CHAPTER IV

ENHANCEMENTS FOR THE B-1B BOMBER

A sophisticated weapon system like the B-1B bomber is never really complete. As the B-1B was being deployed, the Air Force began to analyze how to incorporate new technology to improve reliability, to adjust to changing defensive threats, and to expand the bomber's capability to penetrate Soviet air defenses. On the one hand, this ongoing analysis could lead to programs that lengthen the life and expand the role of the B-1B, squeezing more service out of the original investment. On the other hand, the process could result in procurement of expensive modifications that may not be essential for the bomber's mission. Thus, it is necessary to weigh each enhancement carefully.

The Administration first requested $59.3 million to enhance the B-1B in its budget proposal for fiscal year 1988.[1] The Congress, however, turned down the request, arguing that the Air Force should concentrate on solving the problems in the B-1B's baseline configuration before beginning enhancements. Furthermore, the Congress forbade the Secretary of Defense to carry out any enhancement of the B-1B unless the enhancement is authorized by law and funds are specifically appropriated for that purpose.[2] The Department of Defense later decided not to submit any requests for B-1B enhancements in its budget for fiscal year 1989.

The debate over B-1B enhancements could be renewed next year, however, when the Congress considers the Administration's budget request for fiscal years 1990 and 1991. This chapter examines 19 enhancements currently being considered by the Air Force. The costs

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1. The Air Force requested $39.8 million in the B-1B account (Program Element 64226F) to begin development of a forward-looking infrared (FLIR) sensor and to begin development of improvements in the B-1B's defensive electronics. The Air Force also requested $19.5 million in an account titled Protective Systems (Program Element 64738F) for work on a countermeasure to more advanced Soviet radars.

2. See Section 244 of the National Defense Authorization Act for Fiscal Years 1988 and 1989.

of the enhancements are based primarily on estimates prepared by the Air Force Aeronautical Systems Division in its proposal for the fiscal year 1990 Air Force budget.

EFFECTS OF DECISIONS ABOUT THE B-2 BOMBER

The merits of the enhancements examined here could be affected by decisions regarding the B-2 "stealth" bomber, which will be designed to minimize the range at which Soviet air defense radars can detect it. Press reports indicate that the United States will begin flight-testing this new bomber sometime this year. The Department of Defense has stated that it plans to build 132 B-2 aircraft at a total cost of $60 billion to $70 billion, with deployment scheduled for the early 1990s.

Because details about the cost, schedule, and capability of the B-2 remain highly classified, it is impossible to analyze fully the impact of deploying this aircraft on the merits of alternative roles for the B-1B and, therefore, on the merits of specific enhancements. Two points seem evident, however. If the United States deploys the B-2 aircraft on schedule, it would be less important that the B-1B be enhanced to increase its ability to penetrate Soviet defenses. But if the B-2 is delayed and one believes it is essential to maintain an effective penetrating bomber, then the urgency of enhancing the B-1B's penetration capability increases. Delays in deploying the B-2 may be caused by the many technical challenges inherent in the B-2 program or by budgetary pressures.

OPTIONS FOR ENHANCING THE B-1B

The Congress could, of course, approve no enhancements to the B-1B bomber or could indefinitely delay consideration. Such action would be consistent with a decision to make no further investments in the B-1B bomber during a period in which the defense budget is growing slowly or decreasing. It might also be consistent with a desire to await progress on the B-2 bomber before making any decisions about enhancing the B-1B. The option to forgo enhancements is not analyzed separately here, however, since the result is the baseline B-1B bomber discussed in the previous three chapters.

The enhancements being considered by the Air Force can be split into four groups. One group would improve basic support systems for navigation, maintenance, communication, and weapons carriage, enhancing the B-1B's performance as either a penetrating bomber or as a standoff bomber that carries cruise missiles. A second group is related to the B-1B's role as a standoff bomber. The third and fourth groups are related to the performance of the B-1B as a penetrating bomber: the third enhances the B-1B's survivability by improving its ability to penetrate Soviet air defenses; the fourth increases the B-1B's flexibility by improving its sensors and mission-planning capability. These functional groupings serve as the foundation for the options discussed below.

OPTION 1: IMPROVE BASIC SUPPORT SYSTEMS

This option would fund enhancements for navigation, communication, maintenance, and weapons carriage, improving the B-1B's performance as either a penetrating or standoff bomber.

Description of Enhancements

Second Inertial Navigation System. Each B-1B bomber currently carries one inertial navigation system (INS), which tracks the bomber's location by measuring its movements from an initial reference point. The INS is quite reliable, but a failure might make it difficult for the B-1B to find assigned targets.[3] Under normal conditions, a satellite-based navigation system such as the Global Positioning System could substitute for the INS, but such systems might be disrupted during a nuclear war by disturbances in the ionosphere. This program therefore would provide a second INS, for which room has been reserved on the B-1B, that would take over if the first one were to fail.

3. The mean time between failures of the INS is currently estimated to be about 500 flight hours but is expected to rise to more than 1,000 flight hours as the system reaches maturity.

This enhancement program would fund procurement of the INS and installation of the system on all B-1B bombers at an estimated cost of $30 million.

Global Positioning System. The GPS is a satellite system that emits signals that enable military forces to establish their precise location. The B-1B can employ the GPS to update its inertial navigation system. The GPS receiver could not fully substitute for the inertial navigation system, however, since it is dependent on satellite signals that might be disrupted by anomalies in the ionosphere induced by nuclear detonations.

This enhancement program would pay for the procurement and installation of support equipment for the GPS receivers such as power supplies, wiring, and cooling systems at an estimated cost of $60 million. The development and procurement of the receivers themselves would be paid for by the GPS program. This division of funding, in which the aircraft program pays for the components needed to install the new system while the system's program pays for development and procurement, is in accordance with standard Air Force practice.

MILSTAR Communications Satellite System. MILSTAR satellites are being designed to enable command centers to maintain communications with forces during a nuclear war. To accomplish this, the satellites will operate in the super high frequency (SHF) and extremely high frequency (EHF) bands of the radio spectrum. Using these frequencies minimizes disruptions (such as absorption of radio signals and scintillation) that can be caused by a high-altitude nuclear detonation.

This program would fund only the procurement and installation of support equipment for the MILSTAR terminals; the MILSTAR program will pay for the development and procurement of the antennas and terminals. The estimated cost of the enhancement program is $190 million.

Reliability and Maintainability Program. This program would fund solutions to identified shortcomings in parts, support equipment, and software for the B-1B bomber--for example, the redesign of parts such as the B-1B's windshield, which has in some cases delaminated, and one type of generator that has repeatedly failed. The program would also fund additional support equipment for cruise missiles and radars and would revise some of the software for the Central Integrated Test System. This program would cost about $590 million.

Maintaining Hardness Against a Nuclear Blast. Many electronic components of the B-1B have been "hardened"--that is, designed to resist damage from high-altitude electromagnetic pulse (HEMP), a powerful surge of radio waves caused by a high-altitude nuclear detonation. This program would procure support equipment for testing and maintaining the hardness of B-1B components both aboard the aircraft and at maintenance shops at the B-1B's main operating bases. The estimated cost is $30 million.

Interface for External Weapons. The baseline B-1B has been designed to carry the ALCM-B cruise missile externally. This program would also enable the B-1B to carry externally future conventional or nuclear munitions by providing a new "interface"--that is, the wiring and electronics necessary for current B-1B equipment to communicate with the future munitions. The new interface is based on a set of requirements known as Military Standard #1760.

The specific weapons for which this interface would be used are either classified or yet to be designed. The external interface would not be required for the advanced cruise missile, which will employ the existing interface. Also, this new external interface would probably not be used to support the SRAM II. Although the SRAM II would be compatible, the Air Force will probably only carry it internally since it is designed for use on penetrating missions. Carrying the SRAM II externally on such missions would have the undesirable effects of increasing drag, which would decrease the bomber's range, and of increasing the bomber's radar cross section, which would make it easier for enemy radars to track the bomber.

Although probably not intended to support the advanced cruise missile or SRAM II, the #1760 interface would enable the B-1B to carry classified or future munitions that could conceivably enhance the B-1B's capability as either a penetrating bomber or as a cruise missile carrier. To enhance penetration, the B-1B bomber might carry missiles designed to attack or decoy Soviet fighter-interceptors, to attack Soviet AWACS, to destroy ground-based radars (by detecting and following radar emissions to their source), to collect reconnaissance data while flying at a high altitude and relay it to the low-altitude bombers.

Such missiles could also enhance the B-1B's future effectiveness as a cruise missile carrier by complicating Soviet efforts to intercept the bombers before they launch their cruise missiles or by relaying reconnaissance data to the cruise missiles assigned to attack mobile targets. Finally, the B-1B could carry advanced munitions externally to improve its capabilities in conventional conflicts. Precision-guided standoff munitions might improve both the B-1B's survivability and the accuracy with which munitions are delivered. This program would cost about $790 million.

Other Enhancements for Support Systems. As other navigation or communication systems are procured, the Air Force will probably plan on modifying the B-1B to accommodate them when appropriate. One other enhancement, the integration of miniature receiver terminals designed for receiving messages over low-frequency radio, is also planned. The special equipment required to accommodate the terminals was installed in 69 B-1Bs during production. The equipment for the remaining B-1Bs will be funded under the B-1B modernization account.

Discussion

The enhancements to basic support systems included in this option would contribute to the B-1B's capability regardless of its mission and therefore are not related to the debate concerning the future role of the B-1B. They would, however, add to costs. Based on the Air Force's preliminary estimates, the programs in this option would cost about $1.2 billion over the next five years and $1.7 billion in total (see Table 1). The main argument against making these enhancements may be budgetary limits, which might be severe in coming years.

But several of these enhancements are not very controversial. Whether the B-1B is operating as a penetrating bomber or as a cruise missile carrier, it is important to maintain or improve its reliability and its hardness to electromagnetic pulse. Since the United States is spending billions of dollars to develop and deploy the GPS and

MILSTAR satellites, it makes sense to enable the B-1B bomber to use the navigation and communication capabilities they provide. Similar rationales might apply to the most expensive program in this option--providing the #1760 interface for external munitions--but that cannot be determined fully in this study since the Air Force's plans for the specific munitions the B-1B would carry are classified.

OPTION 2: IMPROVE THE B-1B's CAPABILITY TO CARRY CRUISE MISSILES

Since the capability to carry cruise missiles internally and externally was incorporated into the design of the B-1B, only two minor programs are required to transfer most B-1Bs from the penetrating mission to the standoff or shoot-and-penetrate missions in which the bomber would carry cruise missiles.

TABLE 1. COST OF OPTIONS FOR ENHANCING THE B-1B
(In millions of current dollars)

	1990	1991	1992	1993	1994	1990-1994	Cost to Complete	Total Cost
Option 1: Improve Basic Support Systems	380	230	280	150	130	1,170	520	1,690
Option 2: Improve the B-1B's Capability to Carry Cruise Missiles	60	20	5	5	a/	90	0	90
Option 3: Improve the B-1B's Survivability as a Penetrating Bomber	380	540	540	440	180	2,080	1,290	3,370
Option 4: Improve the B-1B's Flexibility as a Penetrating Bomber	200	300	380	540	460	1,880	860	2,740
Total	1,020	1,090	1,205	1,135	770	5,220	2,670	7,890

SOURCE: Congressional Budget Office based on Air Force estimates.

a. Less than $1 million.

Description of Enhancements

Cruise Missile Capability. Because the B-1B was produced on a very fast schedule, seven B-1Bs at the beginning of production came off the line without the capability to carry cruise missiles. These B-1Bs need a movable bulkhead between the front and middle weapon bays to accommodate cruise missiles internally and also need modifications to the fuselage to carry cruise missiles externally. These changes, along with the necessary wiring and software, would cost about $60 million.

External Observable Differences. Both the SALT II strategic arms agreement and the draft of the START agreement on strategic arms being negotiated in Geneva require the United States and Soviet Union to distinguish their bombers that carry cruise missiles from those that do not. Consequently, an Air Force Program Management Directive requires B-1B bombers that are carrying cruise missiles, including test aircraft, to display an "external observable difference" (EOD). This enhancement program funds the design, development, and installation of an EOD that would, among other things, minimize aerodynamic disturbances and effects on the aircraft's radar cross section. The estimated cost of this enhancement is $30 million.

Discussion

One of the major issues regarding this option, which does not fund programs to enhance penetration, is how long the B-1B can continue to be an effective penetrator without such enhancements. As discussed in Chapter III, the answer to this question depends on many factors, some of which can be controlled by the United States (for example, tactics such as the number of ballistic missile warheads dedicated to suppressing Soviet air defenses) and some which cannot (for example, whether a Soviet attack is preceded by a crisis or comes out of the blue).

The Air Force, having weighed these factors, has testified that the baseline B-1B without enhancements will be an effective penetrator at least through the mid-1990s. This conclusion would fit with the discussion in Chapter III of the weaknesses of the current Soviet air defenses and the challenges faced in overcoming them. The difficulty the Air Force is having in completing the B-1B's defensive avionics, however, might alter this conclusion.

Advantages. This option would complete preparations for using the B-1B as a standoff bomber. In the near term, this gives the B-1B the flexibility to operate in any of three roles: penetration, shoot-and-penetrate (launching externally carried cruise missiles before penetrating the Soviet Union), and standoff. Although the Air Force might prefer to continue to use the B-1B as a penetrating bomber as long as its probability of completing its mission is acceptable, under this option it could be easily transferred to the other roles as improved Soviet air defenses decrease that probability to an unacceptable level.

Operating the B-1B in a standoff role has several positive aspects. If the Soviet Union pursued a strategy of forward interception, the B-1B's small frontal radar cross section would make such interceptions more difficult. With the ACM, the B-1B will be able to launch its cruise missiles at greater distances from the Soviet Union, further increasing the difficulty of forward interception. And, on standoff missions, the B-1B will need less support from tanker aircraft, freeing tanker assets for other missions. By combining the capability of a standoff bomber to inundate defenses with cruise missiles and the stealth characteristics of the ACM, the B-1B as a standoff bomber should be an effective strategic weapon well into the next century.

Nor would this option adversely affect the B-1B's capability in many conventional conflicts. First, as discussed in Chapter III, because of the increasing sophistication of air defenses in many regions of the world and the lower acceptable level of attrition on conventional missions, standoff weapons are gaining favor over bombs for attacking fixed targets in conventional conflicts. This option is consistent with that trend. In addition, if a choice were made to use the B-1B as a penetrating conventional bomber--perhaps against undefended targets--the penetrating capability of the baseline B-1B maintained in this option would serve well.

This option also is consistent with the Administration's original two-bomber plan supporting procurement of the B-2 stealth bomber. If the B-1B will be an effective penetrator through the mid-1990s, and if the B-2 is deployed in the early to mid-1990s as the nation's primary penetrating bomber, then it might be unnecessary to invest in additional enhancements for the B-1B as a penetrator and might be appropriate to prepare the B-1B for transition to a shoot-and-penetrate role and eventually a standoff role.

Finally, the enhancements under this option are relatively inexpensive. Based on preliminary estimates by the Air Force, the enhancement programs in this option would cost a total of about $90 million, all spent over the next five years (see Table 1). A decision to pursue these enhancements, however, might be logically coupled with a decision to enhance basic support systems as discussed in Option 1. Both options together would cost about $1.8 billion.

Disadvantages. One problem with this option is that the Air Force is having difficulty completing the baseline B-1B's defensive avionics, so the baseline B-1B might not be an effective penetrator for as long as the Air Force has anticipated.

More important, if the B-2 is not deployed, or if its deployment is delayed significantly because of budgetary limits or technical problems with the new aircraft, the United States could find itself without an effective penetrating bomber. From the viewpoint of advocates of penetrating bombers, that would be a major mistake since the United States would forfeit the advantages of these bombers.

Even if the B-2 is deployed, the United States might want to maintain more than 132 penetrating bombers (the planned number of B-2s) both for traditional missions against fixed sites and for missions against the growing number of Soviet mobile facilities. Because of the B-2's high costs, maintaining the B-1B as a penetrating bomber for an extended period might be the only affordable way to deploy a larger fleet of penetrating bombers. Doing so, however, might require enhancements beyond those included in this option.

OPTION 3: IMPROVE THE B-1B'S SURVIVABILITY AS A PENETRATING BOMBER

The ability of the baseline B-1B to penetrate Soviet defenses will decline as Soviet air defenses improve. This option would endeavor to prevent that decline, seeking to maintain the B-1B as an effective penetrator beyond the year 2000. In particular, this option provides for integrating an improved short-range attack missile and for improving defensive and offensive avionics. With these enhancements, the B-1B should be better able to foil advanced Soviet look-down/shoot-down air defense technology and, when that fails, to destroy defensive threats.

Description of Enhancements

Integration of SRAM II. The SRAM II is expected to have better reliability, accuracy, range, and targeting flexibility than the current SRAM-A, helping the B-1B to penetrate Soviet air defenses by improving its ability to destroy air defense installations encountered en route to a target. To carry the SRAM II in its weapon bays, however, the B-1B needs a new weapon interface. This enhancement program would provide that interface. It would be based, like the interface for external munitions discussed in Option 1, on Military Standard #1760. To save money, the Air Force does not intend to conform to all requirements in that standard. The interface, for example, would use standard wires rather than fiber optics for carrying signals.

This program would procure and install the interface. It would not pay either for development or for testing, which are funded in other programs. This enhancement would cost about $610 million.

Monopulse Countermeasure. Several of the most sophisticated Soviet air defense systems use a monopulse tracking radar. A monopulse radar uses a single pulse to establish both the azimuth and elevation of a target. This enhancement program would strive to develop and deploy the best possible countermeasure to these advanced Soviet systems. The estimated cost of this enhancement is about $1.4 billion.

Forward Warning System. As noted in Chapter II, the baseline B-1B's defensive avionics will include a tail warning function--a radar system that searches for air-to-air missiles approaching the B-1B bomber from the rear. The forward warning system would do the same for missiles approaching the B-1B from the front. This capability would be particularly useful for detecting "all-aspect" infrared-guided missiles that the Soviet Union might deploy in the future. Development, procurement, and installation of this system would cost about $660 million.

Improved #1122 Countermeasure. This program would improve the classified #1122 electronic countermeasure to Soviet air-to-air missiles. This program would cost about $60 million.

Research and Development Assets. Laboratories currently use parts from the spares inventory to conduct developmental testing on the B-1B's defensive avionics. This enhancement program would purchase additional assets specifically for the development program. The estimated cost of this enhancement is $170 million.

Operation of Anechoic Chamber. The Air Force is building a large anechoic chamber (the walls absorb electromagnetic waves, eliminating echoes) for testing the avionics of many aircraft, including the B-1B. Using this chamber, the Air Force can test the response of the B-1B's defensive avionics to Soviet electronic countermeasures, and the integration of the B-1B's offensive and defensive avionics. An important advantage of this chamber is that the Soviet intelligence network will not be able to pick up the emissions and exploit them to design countermeasures.

This program would rent a specific amount of time in the chamber for testing the B-1B over a five-year period (the rental fee pays for the cost of maintaining and operating the chamber; construction was financed under a separate account). Using the chamber would be particularly helpful in developing and testing revised architectures for the B-1B's defensive avionics system. The Air Force estimates the cost of renting this chamber for testing the B-1B to be about $70 million for 1990 through 1994.

General Avionics Enhancements. This program would fund ongoing improvements in the offensive and defensive avionics such as increased computer memory, computational speed, and data storage. It would also seek to improve the "man-machine interface," modifying the way that terrain-following profiles, radar-generated maps, and defensive threats are displayed in the cockpit. The estimated cost of this enhancement program is $360 million.

Other Enhancements. The Air Force, as noted in Chapter II, is currently studying alternatives for changing the basic architecture of the B-1B's ALQ-161 defensive avionics system. When that study is completed in October 1988, the Air Force will probably propose a specific program for designing and implementing the revised architecture. The Air Force might request funds for that program under the B-1B baseline program or under a separate enhancement program. As more is learned about specific Soviet air defense systems, the Air Force will most likely consider other programs. For example, the service might seek to modify the B-1B's infrared signature, improve the bomber's chaff and flares, decrease reliance on active radar for terrain-following, or perhaps employ new types of towed, ejected, or free-flying decoys.

Discussion

This option is a package of enhancements designed to maintain or improve the capability of the B-1B to penetrate Soviet air defenses despite improvements in those defenses.

Advantages. The enhancements in this option would increase the probability that the B-1B would be an effective penetrating bomber beyond the year 2000. For proponents of penetrating bombers, this ensures that the United States will have an effective penetrator even if problems arise in the design and production of the B-2.

Proponents on all sides of the debate over penetrating bombers and standoff bombers might find merit in the fact that this option would reduce the pressure for building the new B-2 immediately, possibly enabling the program to proceed at a more measured pace that lowers the risks inherent in concurrent development and production. In addition, before making a commitment to produce the expensive B-2 bomber, the Congress could use the additional time to ascertain that the B-2 offers advantages that have not already been largely realized through the development of cruise missiles.

Disadvantages. Expense is a major drawback to this approach. This option is expected to cost about $3.4 billion, with $2.1 billion to be spent over the next five years compared with about $90 million for Option 2. As with Option 2, Option 3 could be pursued in tandem with

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the enhancements to basic support systems under Option 1. The combined cost of Options 1 and 3 would total about $5.1 billion.

The costs of this option are only part of the costs of maintaining the B-1B as a penetrator beyond the turn of the century. If that is the goal, it makes sense to deploy on the B-1B the new SRAM II short-range missile, currently scheduled for initial procurement in fiscal year 1991 and deployment by April 1993. Procuring the SRAM II for the B-1B might cost an additional $600 million to $700 million.[4] On the other hand, if the Air Force maintained the B-1B under this option only as a penetrator, the Air Force might choose to delay the advanced cruise missile, saving money.

Nor is it clear that these added funds provide additional capabilities that are critical to maintaining the B-1B as an effective penetrator beyond the year 2000. As noted in Chapter III, the United States can influence the B-1B's effectiveness as a penetrator through choice of tactics and missions. In addition, weaknesses in future Soviet air defenses, such as the potential vulnerability of Soviet AWACS to attacks by fighters, might prevent those defenses from becoming a significant threat to the B-1B's ability to penetrate.

In the opinion of cruise missile proponents, this option spends money without achieving any significant capability not currently possessed by standoff bombers equipped with cruise missiles. Proponents argue that cruise missiles are good penetrators currently and offer flexibility for enhancements that could match improvements in the Soviet air defenses.

OPTION 4. IMPROVE THE B-1B'S FLEXIBILITY AS A PENETRATING BOMBER

Like Option 3, this option is designed to improve the B-1B as a penetrating bomber. Rather than improve its survivability, however, this option would improve its flexibility, better enabling it to attack dif-

4. The Air Force estimates that procuring the SRAM II will cost about $0.8 million per missile. The additional cost of procuring SRAM IIs under this option is based on procuring eight SRAM IIs for each of the 99 B-1B bombers.

ferent types of targets--particularly mobile targets--under varied conditions.

Description of Enhancements

Improved Synthetic Aperture Radar. The eye of the offensive avionics system is a synthetic aperture radar in the nose of the B-1B bomber. One important function of this radar is to make high-resolution maps of the ground. This enhancement program would upgrade the resolution of those maps and provide target-recognition software to help the B-1B crew detect mobile targets such as mobile Soviet ICBMs. The estimated cost of developing and deploying this sensor is $640 million.

High-Resolution Infrared Sensor for Targeting. A forward-looking infrared (FLIR) sensor records emissions in the infrared sector of the electromagnetic spectrum, much as a television camera records emissions in the sector of visible light. Electromagnetic emissions in the infrared sector are caused by heat, and a FLIR sensor maps features (such as hills, roads, and rivers) by distinguishing between their respective temperatures.

The goal of this enhancement program is to produce a FLIR sensor that has high enough resolution not only to see major features of the terrain but to distinguish between types of trucks, improving the ability of the B-1B crew to find and identify mobile targets. This program would also provide a laser range-finder and would be designed to facilitate interaction with any target recognition system (such a system would alert the crew when the sensor detects a potential target) that might be developed in the future.

The high-resolution FLIR sensor and laser range-finder might also provide a substitute for the automatic terrain-following radar system the B-1B currently employs. Whereas the ATF system emits radar energy that could disclose the B-1B's location to future Soviet ground-based sensors, the infrared sensor does not.

The Air Force estimates that the cost of developing and procuring this enhancement would be $1 billion.

On-Board Mission Planning System. This system would have two basic functions: it would create a "paperless cockpit" by providing electronic displays of checklists, maps, and combat mission folders; and it would create an electronic workstation for calculating potential changes in a mission. For example, if a B-1B were to receive information about a potential mobile target or concentration of air defenses during a mission, this system would help the crew to calculate the possible consequences of various responses. The Air Force estimates that the cost of this option would be about $590 million.

Low-Resolution Infrared Sensor for Situational Awareness. During a penetrating nuclear mission, the B-1B crew would have no continuous indication--or "situational awareness"--of the surrounding terrain. Visual contact with the ground is largely limited by a special curtain drawn across the cockpit window to protect the crew from the flash of light from a nuclear detonation. Although the offensive radar system can create images of the surrounding terrain, its primary task is to supply data to the automatic terrain-following system to keep the bomber close to the ground.

A forward-looking infrared (FLIR) sensor for situational awareness would provide that continuous indication of surrounding terrain. The resolution of the FLIR is not high enough to aid targeting, but it would keep the crew aware of their surroundings, avoiding surprises while flying at low altitudes to penetrate enemy territory. The system also would facilitate nighttime landings at unlit airfields. The Air Force estimates that this sensor would cost $370 million. To use either this sensor or the targeting FLIR sensor discussed above, the Air Force also would need a display system, which would cost an additional $130 million, for a total of $500 million.

Discussion

The sensors and on-board mission planning system are intended to improve the flexibility of the B-1B as a penetrating bomber, potentially improving its performance in finding and attacking mobile targets, conducting a damage assessment/strike mission, or performing conventional missions.

Advantages. The enhancements in this option would better enable the bomber to conduct missions against mobile targets. The improved synthetic aperture radar (SAR) and the targeting FLIR sensor would provide more data than the B-1B's current SAR on the location of systems such as mobile Soviet ICBMs. The on-board mission planning system would begin to provide the autonomous planning capability necessary to respond to a flow of data regarding the potential location of a mobile target. Such data might come from space-based sensors, high-flying intelligence aircraft, or expendable drones.

The enhanced SAR and targeting FLIR sensor might also improve the B-1B's ability to conduct a damage assessment/strike mission in which the bomber crew flies the bomber over a target, determines whether a previous attack has destroyed it, then decides whether to attack it again.

This option would also increase the capability of the B-1B bomber in a variety of nuclear and conventional missions by improving its low-altitude navigation with the low-resolution FLIR.

Disadvantages. The enhancements in this option are expensive. The price tag of $2.7 billion, when converted to constant 1981 dollars, is 7 percent of the $20.5 billion invested in developing and procuring the baseline B-1B. Viewed in terms of opportunities forgone, the funds needed to finance Option 3 would buy a substantial share of the advanced cruise missiles required to equip a fleet of standoff B-1B bombers.

Given the goal of maximizing the B-1B's performance as a penetrating bomber, it would be logical to combine this option with Option 1 (to improve basic support systems) and Option 3 (to improve the survivability of the B-1B as a penetrating bomber). The cost of the combined options would be $7.8 billion--about 21 percent of the amount invested in developing and procuring the baseline B-1B.

The enhancements in this option are basically unrelated to the B-1B's ability to accomplish its current primary mission of penetrating Soviet air defenses and attacking fixed targets. Consequently, unless the B-1B is assigned the mission of finding and attacking mobile targets, these enhancements might contribute little to the bomber's performance.

In addition, it is not clear that this option would provide any significant capability to find and destroy mobile Soviet targets. To establish that the sensors funded under this option would provide such a capability, more detailed information is needed regarding, among other factors, the capability of sensors and their susceptibility to decoys and deception (see Chapter III). The development of the plans for the sensors and their use on the B-1B appears to be too rudimentary to provide a foundation for evaluating these crucial questions.

Even if the sensors provided a significant capability to find mobile missiles, such a task might not be a wise use of the B-1B bomber because it might divert the bomber from other, more important, missions or increase the bomber's vulnerability to Soviet air defenses (the B-1B might have to fly more slowly and at higher altitudes to use its sensors effectively).

Before undertaking an expensive plan to enable the B-1B to search for mobile targets, comparisons should be made between using the B-1B for that mission and using ICBMs, SLBMs, cruise missiles, and the B-2. Because the necessary sensor capability has not been demonstrated yet, it is not possible to make such comparisons. Moreover, from a policy standpoint it is not clear that it is essential, or even desirable, that the United States aggressively pursue the capability to destroy mobile Soviet targets.

Other Enhancements. As the operational concept for attacking mobile targets develops and new technologies mature, the Air Force will probably plan additional enhancements for expanding the B-1B's flexibility as a penetrating bomber. Those enhancements might involve measures to increase its range, such as carrying external fuel tanks, or additional methods to improve the B-1B's search capability. Millimeter-wave radar, for example, is being explored as a complement to infrared sensors for finding mobile targets.

Finally, the purposes of the low-resolution FLIR sensor--improving the crew's awareness of the terrain over which the bomber is flying and enhancing nighttime landings--do not appear to be essential for conducting either penetrating or standoff missions. The cost must therefore be weighed against a marginal contribution to the B-1B's primary missions.

CONCLUSION

Although the Air Force is actively considering the B-1B enhancements discussed in this paper, they have not been formally presented to the Congress. The Department of Defense may choose to present some or all of them, however, as part of its fiscal year 1990 budget.

Nevertheless, it might be appropriate for the Congress to begin considering these options, since they are related to difficult questions such as the current and future capability of the B-1B to penetrate Soviet air defenses and the relative merits of penetration versus standoff tactics. Moreover, decisions about enhancements for the B-1B bomber may affect other decisions that will be made this year regarding the pace of development and procurement for the advanced cruise missile, the SRAM II short-range missile, and the B-2 stealth bomber. Finally, some of the enhancements are directly related to the search for a method to attack the growing number of mobile Soviet targets.

APPENDIXES

APPENDIX A

METHODOLOGY FOR CALCULATING THE PAYLOAD CAPACITY AND RANGE OF THE B-1B ON TERRAIN-FOLLOWING MISSIONS

The B-1B was designed to carry a large payload (fuel and munitions) while flying at low altitudes, following the terrain to escape detection by Soviet radars. Currently, however, the bomber cannot, during terrain-following flight, carry as large a payload as anticipated. Therefore, for any given load of munitions, it can carry less fuel than planned, reducing its operational range.

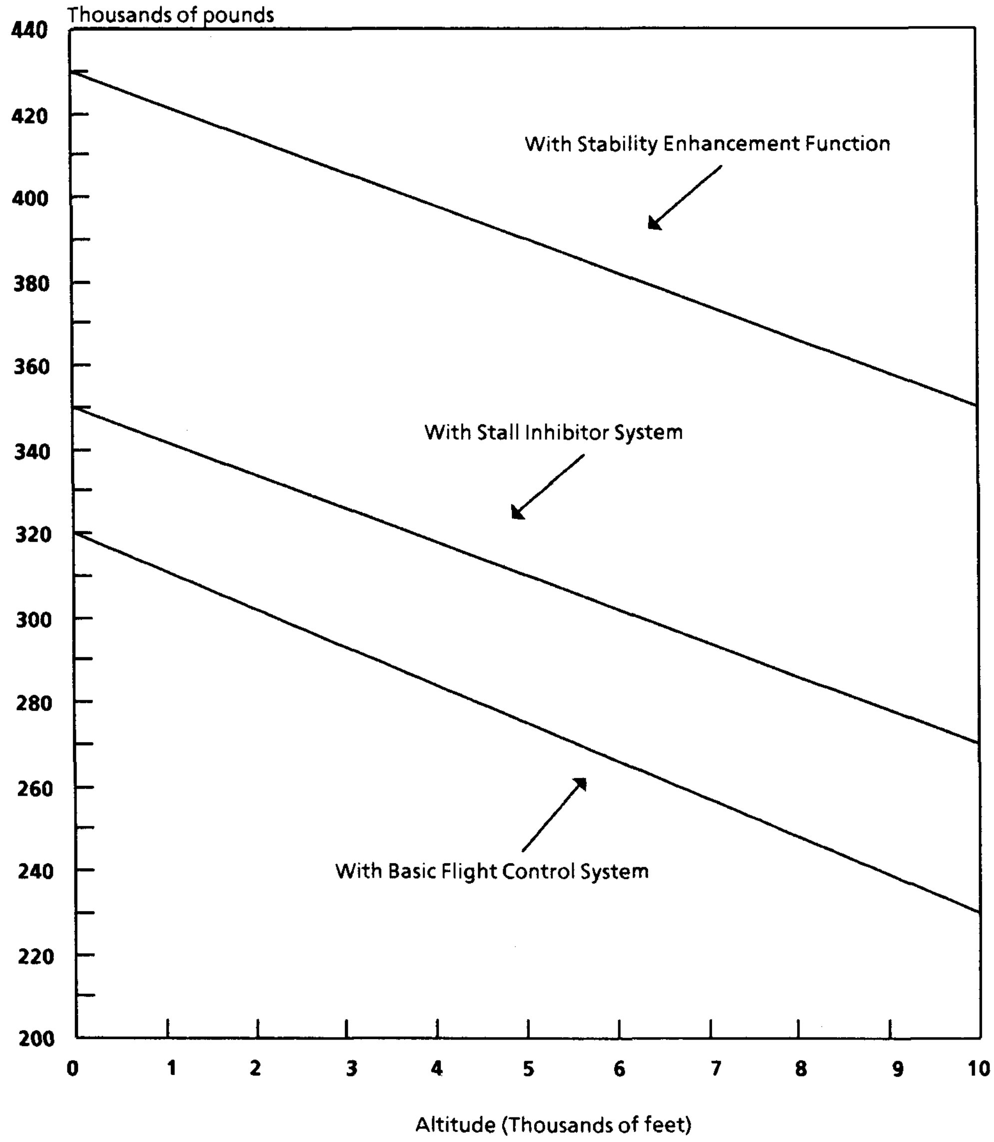
PAYLOAD CAPACITY

As depicted in Figure A-1, the Air Force estimates that the B-1B equipped with the basic flight control system (FCS) can fly safely--that is, can maintain the maneuvering capability desired by the Air Force of 2.4 g's (gravitational equivalents) for 10 seconds--with a maximum gross weight of 312,000 pounds at 1,000 feet (equivalent to flying 200 feet above land that has an altitude of 800 feet).

When the B-1B's flight control system is modified with the Stall Inhibitor System (SIS) or Stability Enhancement Function (SEF), the bomber will be able to fly safely at a higher angle of attack, increasing the amount of weight it can carry while maintaining the desired maneuvering capability. The Air Force estimates that when the B-1B is flying at an altitude of 1,000 feet, it will have a maximum gross weight of 342,000 pounds with SIS and about 422,000 pounds with SEF (see Figure A-1). The estimate for SIS is based on substantial testing, but the estimate for SEF is based on preliminary engineering evaluations and could change substantially.

The payload capacity of the B-1B at low altitudes is equal to the maximum gross weights noted above minus the weight of the bomber itself. Thus, as presented in Table A-1, the payload capacity of the B-1B equipped with the basic flight control system is about 125,000

Figure A-1.
Gross Weight Limits of the B-1B During Terrain-following Flight



Assumptions: Bomber is flying with a wing sweep of 67.5 degrees at velocity of Mach .85, maintaining the ability to pull up at an acceleration rate of 2.4 g's (gravitational equivalents) for 10 seconds.

SOURCE: U.S. Air Force.

pounds. The payload of the B-1B equipped with SIS increases to about 155,000 pounds. With SEF, the payload is about 234,000 pounds.

RANGE

The B-1B's range during low-altitude, terrain-following flight depends on the amount of fuel it can carry, which in turn depends both on the bomber's payload and on the amount of the payload dedicated to munitions. For example, the range could be calculated based on a full load of 24 SRAM-As which, with support equipment, would weigh over

TABLE A-1. CALCULATION OF THE B-1B's PAYLOAD CAPACITY (In pounds)

	B-1B Equipped With:		
	Basic Flight Control System	Stall Inhibitor System	Stability Enhancement Function
Maximum Gross Weight for Flying at Low Altitudes[a]	312,000	342,000	422,000
Weight of the Basic B-1B			
B-1B empty	182,360	182,360	182,360
Crew	900	900	900
Miscellaneous equipment and supplies[b]	3,630	3,630	3,630
Fuel tank in bomb bay	n.a.	n.a.	1,130
Payload Capacity	125,110	155,110	233,980

SOURCE: Congressional Budget Office using data supplied by the U.S. Air Force.

NOTE: n.a. = not applicable.

a. Assumes that the bomber is flying at an altitude of 1,000 feet above sea level. This would be the case, for example, if the bomber were flying 200 feet above land having an altitude of 800 feet (see Figure A-1).

b. Includes parachutes, food, water, engine fluids, inaccessible fuel, flares, and chaff.

59,000 pounds. The Air Force, however, would probably not send the B-1B on a strategic mission with that large a load. This analysis assumes instead that the B-1B is carrying a lighter load of eight SRAM-As and eight B61 bombs, leaving one bomb bay empty for carrying fuel. With this assumption, and some fuel set aside for recovering to a friendly base following the low-altitude flight, the B-1B has about 79,000 pounds of fuel for its low-altitude flight when equipped with the basic flight control system, 109,000 when equipped with SIS, and--if the preliminary Air Force estimates prove accurate--188,000 pounds for the B-1B equipped with SEF (see Table A-2).

The B-1B's range during terrain-following flight is affected by the bomber's velocity as well as by the amount of fuel it can carry. This

TABLE A-2. DISTRIBUTION OF THE B-1B'S PAYLOAD WHEN THE BOMBER CARRIES EIGHT SRAM-As AND EIGHT B61 BOMBS (In pounds)

	B-1B Equipped With:		
	Basic Flight Control System	Stall Inhibitor System	Stability Enhancement Function
Payload Capacity	125,110	155,110	233,980
Munitions			
Eight SRAM-As	17,680	17,680	17,680
Eight B61 Bombs	6,010	6,010	6,010
Support equipment	4,130	4,130	4,130
Fuel Needed for Recovery[a]	18,300	18,300	18,300
Fuel Available for Low-Altitude Flight	78,990	108,990	187,860

SOURCE: Congressional Budget Office analysis of data supplied by the U.S. Air Force.

a. The B-1B specifications for recovery require that the bomber, following its low-altitude approach to and escape from the target, be able to fly 575 miles (500 nautical miles) at an altitude and velocity that maximize fuel-efficiency and to loiter for 30 minutes while preparing to land.

study assumes that the bomber's low-altitude flight has two parts: a longer approach to the target (two-thirds of the total low-altitude flight) at the higher speed of about 650 miles per hour; and a shorter escape from the target at about 420 miles per hour.

The B-1B's range, given these assumptions, depends on its fuel efficiency. Based on Air Force estimates for the fuel efficiency of the bomber at various gross weights, the B-1B equipped with the basic FCS could fly a terrain-following mission of 1,480 miles. No allowance is made in this calculation, however, for engines operating at less than the specified efficiency, or for extra fuel being expended in flying over varied terrain or in fighting head winds. To plan for such contingencies, this analysis assumes that a 10 percent cushion is necessary. Thus, the B-1B with the basic FCS can undertake a terrain-following mission of about 1,330 miles. The corresponding range for the B-1B with SIS is about 1,820 miles and with SEF is about 3,000 miles.

APPENDIX B

WIDE-AREA TRACKING SYSTEMS FOR SOVIET AIR DEFENSES

The two major challenges in establishing an effective air defense system are to detect and track penetrating bombers and cruise missiles, and to deliver munitions to the appropriate location to destroy them. This appendix discusses techniques the Soviets currently employ or might employ in the future to meet the first challenge. As evident from the discussion below, there are drawbacks to every approach. During a nuclear war in the near future or years from now, the Soviet Union may have a difficult time tracking penetrating bombers and cruise missiles.

GROUND-BASED RADARS

The Soviet Union's air defenses rely primarily on thousands of fixed, line-of-sight radars to find and track enemy bombers. Such radars have several advantages: they can be easily supplied with electrical power, they are inexpensive to maintain, and they can detect high-altitude aircraft at long distances. In addition, the data from many ground-based radars can be communicated to a common processing facility, enabling the radars to operate collectively like a single radar with much greater range. Such a radar network facilitates the coordination of fighters and provides more time for guiding them to intercept a penetrating bomber or cruise missile.

Fixed ground-based radars also have important shortcomings. Because they are easy to locate and very "soft" (not designed to withstand the shock waves generated by a nuclear detonation), they can be targeted and destroyed by U.S. nuclear weapons. Once their location is established, a flight path can be designed to fly around them. Moreover, the range of a single ground-based radar against low-flying aircraft or cruise missiles is limited by the earth's curvature to about

20 to 50 miles.[1] Connecting radars into a network does not solve this problem unless the radars are close enough for their coverage to overlap. There are many gaps between the coverage of Soviet ground-based radars through which bombers might fly undetected.

The Soviet Union could improve its ground-based radar network by deploying mobile radars, which are harder to locate and therefore harder to attack. Because a penetrating bomber or cruise missile might not know where the radars are located (depending on how recently they have been moved), it might not be possible to plan a flight path to avoid them. Mobile radars, however, also have shortcomings. Like fixed line-of-sight radars, they have limited range against low-altitude penetrators. In addition, there are so many potential gaps in the Soviet ground-based network that plugging all of them with mobile radars would require a massive commitment of resources and personnel.

AIRBORNE WARNING AND CONTROL SYSTEM

The primary way in which the Soviet Union is seeking to remedy the shortcomings of its ground-based radars is to deploy large radars on aircraft. These aircraft, which are known as Airborne Warning and Control Systems (AWACS), monitor enemy penetrators and coordinate air defenses over a large area. The range of an AWACS is much greater than that of ground-based radars--over 200 miles to the horizon and over 400 miles to another aircraft at a high altitude. When airborne, the AWACS cannot be targeted in advance since its precise location is unknown.

The first Soviet AWACS, the Moss, was relatively ineffective in tracking low-flying bombers and cruise missiles. The more recent Soviet AWACS, the Mainstay, is considered to be much more capable. The Mainstays might patrol near the Soviet borders to track approaching U.S. bombers, providing the greatest possible time to

1. A line-of-sight radar standing 50 feet above the ground theoretically can detect at about 30 miles a bomber flying at 300 feet above the ground. At greater distances, the bomber is hidden by the earth's curvature. The actual detection range might be less than the theoretical range because of the disruption or blocking of radar pulses by terrain features such as hills. The actual detection range might be greater than the theoretical range if the radar is located on a hill.

guide fighters to intercept them. Such patrols would force U.S. bombers to start flying at low altitudes earlier in their flight, perhaps at distances of 300 to 400 miles from Soviet territory. The bombers would have to do this to minimize the distance at which the AWACS can detect them, possibly decreasing the bombers' range (low-altitude flight is less fuel-efficient than high-altitude flight). The Soviet Union has so far deployed only a few Mainstay AWACS, but it is expected to continue expanding the fleet.

The Soviet Mainstay AWACS, however, has several shortcomings. When on the ground, it is vulnerable to a surprise attack. If the Soviet Union tried to counter this vulnerability by keeping its AWACS on patrol continuously during a crisis, their capability would be degraded by the necessity of more frequent repairs. In addition, during a large-scale nuclear war, the United States would probably attack many Soviet airfields with ballistic missiles, complicating the AWAC's efforts to land and refuel. Such refueling might be necessary, since U.S. bombers might not arrive near the Soviet Union until 8 to 10 hours after a strike by U.S. ballistic missiles.[2]

Moreover, if the AWACS were a significant threat, the United States could modify the Strategic Integrated Operational Plan (SIOP, the U.S. blueprint for conducting a nuclear strike) to include the use of fighter aircraft to destroy the AWACS. The AWACS are vulnerable to an attack by fighters because they are large and slow, fly at high altitudes, and emit strong radar signals. The AWACS also might be susceptible to electronic countermeasures designed either to jam or to confuse them.

OTHER RADAR SYSTEMS

The Soviet Union could employ many other technologies to attempt to improve the tracking capability of its air defense system. Possible technologies include over-the-horizon radars, space-based sensors, networks of radio-signal receivers, and radars carried on balloons.

2. Refueling at airfields could be avoided by using tanker aircraft. The Soviet Union could, for example, refuel the Mainstay using the new Soviet tanker, the Midas. It is not clear, however, whether this would be a primary mission for the Soviet Union's small fleet of tanker aircraft.

Over-the-Horizon Radars

Over-the-horizon (OTH) radars use a large antenna array to direct a signal at the ionosphere (an electrically charged band in the upper atmosphere). The ionosphere refracts the signal, sending it back to earth to a location far beyond the horizon. The signal is reflected back to the ionosphere by an object such as an aircraft and refracted back to a receiving antenna array on the earth.[3] The main advantage of this technology is that a single OTH radar can scan a very large area, with ranges of about 500 to 1,800 miles.

The Soviet Union faces several problems in employing this technology to remedy the deficiencies of its ground-based radar coverage. One problem is that the ionosphere is very inconsistent in the polar regions, complicating the use of OTH technology. This is a major problem since most routes for U.S. bombers would pass through the polar region. Another problem is that, during a nuclear war, the United States could alter the properties of the ionosphere--and therefore disrupt OTH radar transmissions--by detonating a ballistic missile warhead outside the ionosphere. The United States could also easily destroy the antenna arrays with ballistic missiles before the OTH radar could help track bombers. Finally, OTH radars are susceptible to electronic countermeasures.

Although the Soviet Union might employ OTH radars for tactical warning, this technology does not appear promising for significantly improving Soviet tracking capability during a nuclear war. Furthermore, although some work is being done on over-the-horizon radars that would use troposcatter or meteor-burst propagation, in place of ionospheric propagation, both techniques have limitations that make them unlikely candidates for providing a full solution to the problem of tracking low-flying bombers and cruise missiles during a nuclear conflict.[4]

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3. The radar uses the Doppler effect in which the frequency of a signal reflected off an object moving toward the radar is increased. This effect allows the radar's computers to sort out the signal bouncing off an aircraft from signals bouncing off the ocean.

4. Troposcatter propagation employs irregularities in the lower troposphere (an altitude of 30,000 to 50,000 feet) to scatter a radar beam back to earth. Meteor-burst propagation uses the highly ionized column of air left by a meteor passing through the atmosphere to reflect a radar beam over the horizon.

Space-based Sensors and Radars

Another way to detect low-flying bombers would be to deploy some type of infrared (heat-detecting) sensor or radar on satellites. An infrared sensor, for example, could take a series of images and use a computer to compare the images, searching for a moving heat source that might represent the exhaust from a bomber's jet engines. Potential advantages of such sensors include low maintenance and wide coverage. Disadvantages might include the initial high cost of building and deploying the satellite; the vulnerability of the satellite to attack by an antisatellite weapon, radiation from an exoatmospheric nuclear detonation, and illumination by ground-based lasers (the lasers might damage the satellite's sensors); and the vulnerability of the communications link with the earth to disturbances in the ionosphere caused by nuclear detonations. The effectiveness of an infrared sensor might also be countered by techniques such as dispersing jet engine exhaust so that the infrared signature is weaker. Space-based radars face similar challenges.

Space-based infrared sensors and radars might eventually contribute to the mission of tracking bombers during a nuclear war. But, at least during the 1990s, they are not likely to represent a major threat to U.S. bombers.

Radio Receivers

Another technology that could be used for wide-area surveillance is the radio-signal receiver, which would detect an aircraft's radio (including radar) emissions. For example, the Soviet Union could use a network of ground-based receivers to track a B-1B by detecting emissions from its terrain-following radar, or an ALCM-B by detecting emissions from its terrain-mapping radar. Unlike a conventional ground-based radar, a receiver does not emit a signal. It might therefore succeed in concealing its location, making it difficult for U.S. penetrators to avoid or destroy it.

For these receivers to contribute to tracking, many thousands would have to be deployed and linked together. If the Soviet Union pursues such a network, U.S. bombers might be able to counter it by using laser rather than radar altimeters and by replacing terrain-following radars with infrared terrain-avoidance systems (passive infrared sensors are used to view the terrain, helping the pilot to fly low without hitting hills). Alternatively, bombers could navigate by correlating their precise position (established by using inertial or satellite guidance systems) with data on altitude drawn from computerized data bases stored on the bombers.

Balloon-carried Radars

Another innovative technique for wide-area tracking is to deploy radars at high altitudes with balloons, which can carry a heavy load for extended periods. The U.S. Navy, for example, awarded a contract in 1987 for a prototype dirigible that would carry a large internal radar 5,000 to 10,000 feet above a Navy fleet, helping to spot enemy aircraft and low-flying missiles.

More study is required to determine the value of this technology. The advantages it gains in range or mobility might be balanced by disadvantages related to cost, flexibility, or survivability.